

CONTROL OF BLOWOUT FIRES WITH WATER SPRAYS

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Control of Blowout Fires With Water Sprays

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Objective: To develop blowout fire suppression technology for offshore oil and gas operations.

Perhaps the most serious of all possible accidents for offshore oil and gas operations is a blowout. Fires resulting from blowouts, in which methane gases and other flammable formation fluids are ignited and burn uncontrollably, can destroy drilling rigs and platforms.

An analysis of available accident data (Evans and O'Neill, in press) shows that, between 1973 and 1980, 10 blowout fires or major explosions occurred on the Outer Continental Shelf (OCS). In the incidents where blowouts occurred on platforms, the actual location of the operational failure varied, that is, the choke assembly, the end of the drill pipe on the drilling deck, the top of the well annulus just below the rotary table, and the flange connections in the blowout preventer (BOP) stack located in the substructure below the derrick.

The Center for Fire Research (CFR) of the National Bureau of Standards (NBS) is investigating the feasibility of controlling blowout fires using a seawater-based, fire-suppression system. It is known that when water is added to hydrocarbon flames, even in small amounts, radiation from the flames is greatly reduced. When larger quantities are added, the flames may be extinguished. The major problem to be overcome in the design of blowout-fire-protection systems is to determine methods of delivering the desired quantity of water and mixing it with the burning hydrocarbons to either control or extinguish fires.

Two methods of injecting water into a flowing system of hydrocarbons were investigated in laboratory experiments. The first and major area of research involved suppression methods applicable to a fire resulting from a blowout through the drill string. In this fire, the flames are likely to be limited to the above-platform deck area in the derrick. It was this type of blowout fire that precipitated the IXTOC disaster in Campeche Bay, Mexico, in 1979. Control of such a fire may be achieved with a spray

system from which water is injected or entrained by air into the flames from external discharge positions, as illustrated in figure 1.

In a second series of laboratory experiments, water droplets were mixed with gaseous fuels flowing in a pipe before burning the mixture at the pipe outlet. This process is representative of a candidate suppression system designed to control blowout fires originating from influxes which

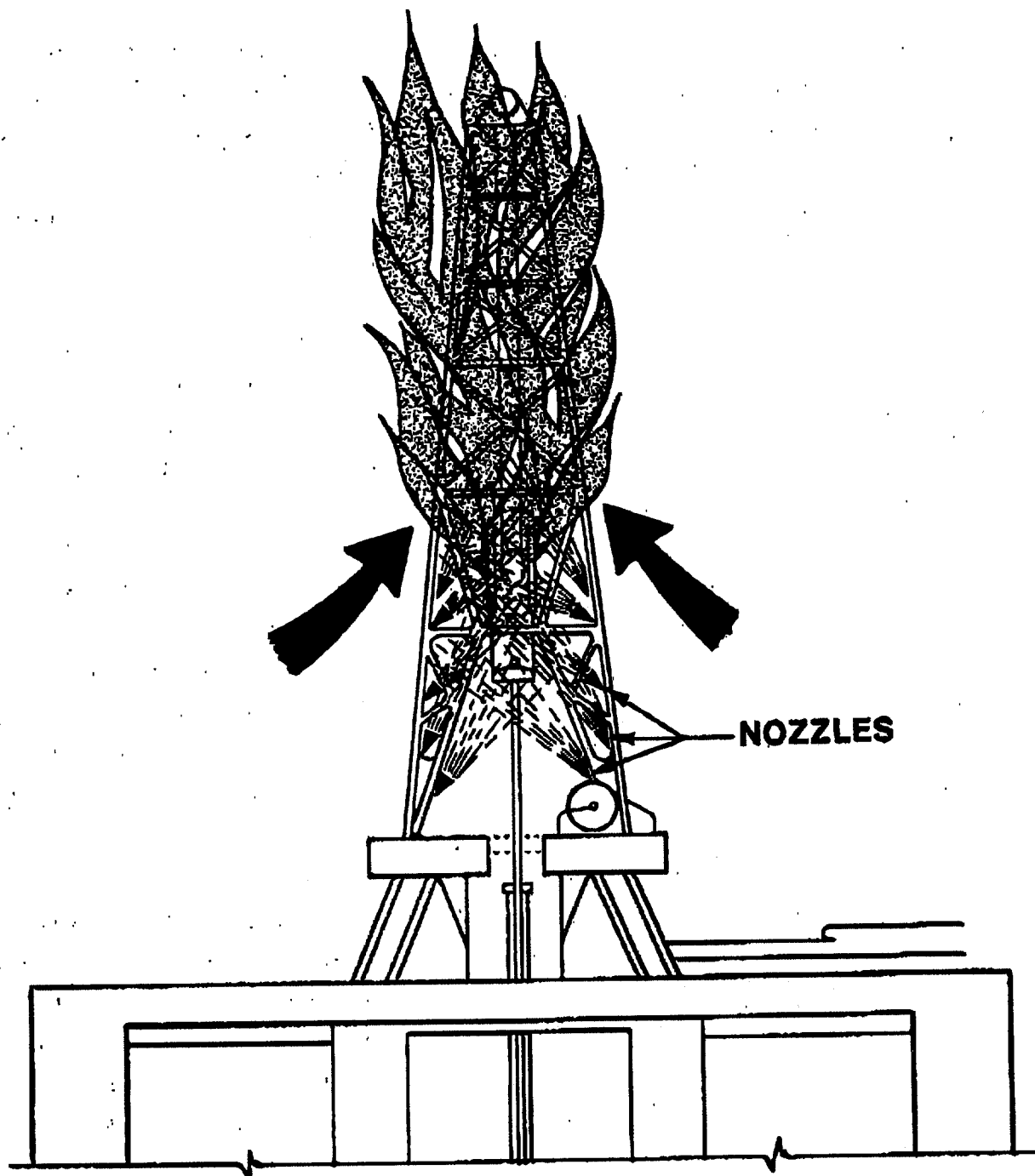


Figure 1.--Fire suppression system for drill string blowout fires.

rise in the well annulus. It also serves, for research purposes, as an idealized limit for the most effective use of the water spray. A survey of available literature performed as part of this research program (Milke, 1982) revealed that very little is known about the interaction of water droplets with diffusion flames. Therefore, there is no technological base using this principle on which to design a blowout fire-suppression system.

A primary objective of the Bureau's research program is to develop a basic understanding of the effects of water spray on diffusion flames from gaseous fuels. This understanding would be used to help specify design requirements for blowout fire-suppression systems capable of controlling gas well blowout fires which have heat release rates in the order of 1,000 MW (90×10^6 ft³/day methane).

The experimental work in this research study consists mainly of detailed laboratory measurements of the effects of water sprays on fires which have heat release rates of 0.01 MW to 0.1 MW. In addition, intermediate-scale 1 MW to 10 MW fire-suppression tests are being conducted to examine the potential of scaling the fire-control process. Tests of a water-spray fire-control system on large 200 MW (18×10^6 ft³/day methane) fires, comparable to small blowout fires, are planned to validate design principles.

Measurements were made on laboratory and intermediate scale fires to quantify the flow of water needed to extinguish high momentum diffusion flames or to reduce overall fire temperatures and radiation from the flames under controlled burning conditions. Using water sprays to control, but not to extinguish a gas-flow fire, is important because in some cases extinguishment of blowout fires may be undesirable. In these cases, water sprays could be used to control fires and to limit damage to platforms by reducing heat loads on structures.

It is obvious that greater flows of water will be needed to control large fires than to control small laboratory fires. In order to make meaningful comparisons of water spray effectiveness on fires for both different spray arrangements and fire sizes, the water flows needed to achieve given effects must be normalized with a measure of the fire size. In this work, the mass flow of water spray is normalized with the mass flow of gaseous fuel.

As part of this research program, McCaffrey (1983) has measured both the reduction of flame radiation and the extinguishment conditions of

propane (C_3H_8) fires as a function of the mass flow ratios of water to propane. These data were collected using a laboratory burner (shown schematically in figure 2) in which water spray is injected with the propane flow before the mixture is burned. For reference, the results of similar experiments, conducted by Gupta (1976), in which argon and steam were premixed with propane are also shown in figure 2.

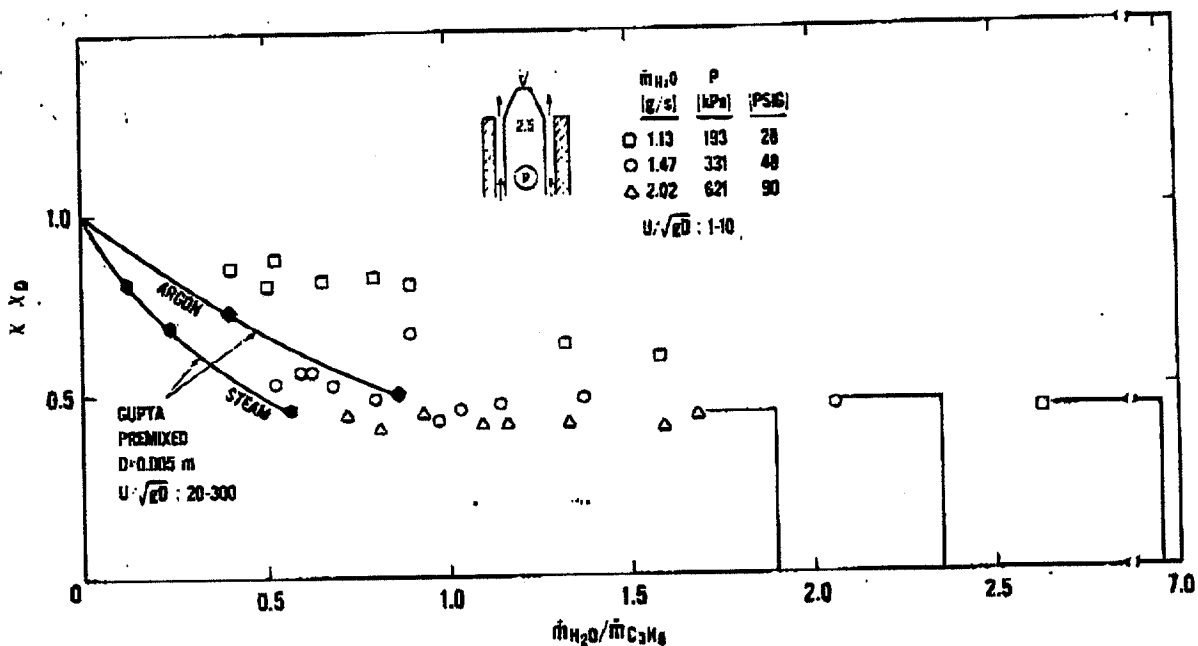


Figure 2.--Reduction in flame retardation and extinction conditions for water-propane mixture.

Results of these experiments are encouraging from the standpoint of developing a blowout fire control system based on water spray. Figure 3 shows a series of photographs documenting the dramatic decrease in visible radiation from the fire as the mass flow ratio of water to propane is increased in laboratory experiments. First, a relatively small water flow is required to significantly reduce radiation. Based on this test work, a limit of 40-percent-to-50-percent reduction can be expected. Second, all these laboratory-size fires were extinguished at water-to-propane flow ratios below 7.0. In separate tests using methane, much larger intermediate-scale fires were extinguished using mass flow ratios below 10.0. Results are encouraging because technology is already available to permit design of practical systems to control full-size blowout fires if,

for these much larger fires, the mass flow ratio of water to gas required for extinguishment remains below 10.0.



Figure 3.--Effect of water spray on propane fire (Nozzle outlet diameter of 18.3 mm).

Cooling of combustion products within the flame has been studied with water spray mixed with the gas flow before burning (interior injection) and mixed with the flow after the fuel gas is ejected from the test pipe (exterior injection). Both are shown schematically in figure 4 together with several temperature measurements made in a 1.14 MW methane flame with and without water injection. Peak temperatures within the flame reach 1100°C (2000°F). Generally, the results show that water injection decreases gas temperature less than 100°C in the upper part of the flame (2.5 m to 5 m above the outlet). In the lower part of the flame, however, the water spray can significantly decrease gas temperatures. In addition, interior sprays are more than twice as effective in reducing gas temperatures in the lower portion of the flame than is the use of an exterior spray. Similar results were obtained for other combinations of fire sizes and water sprays.

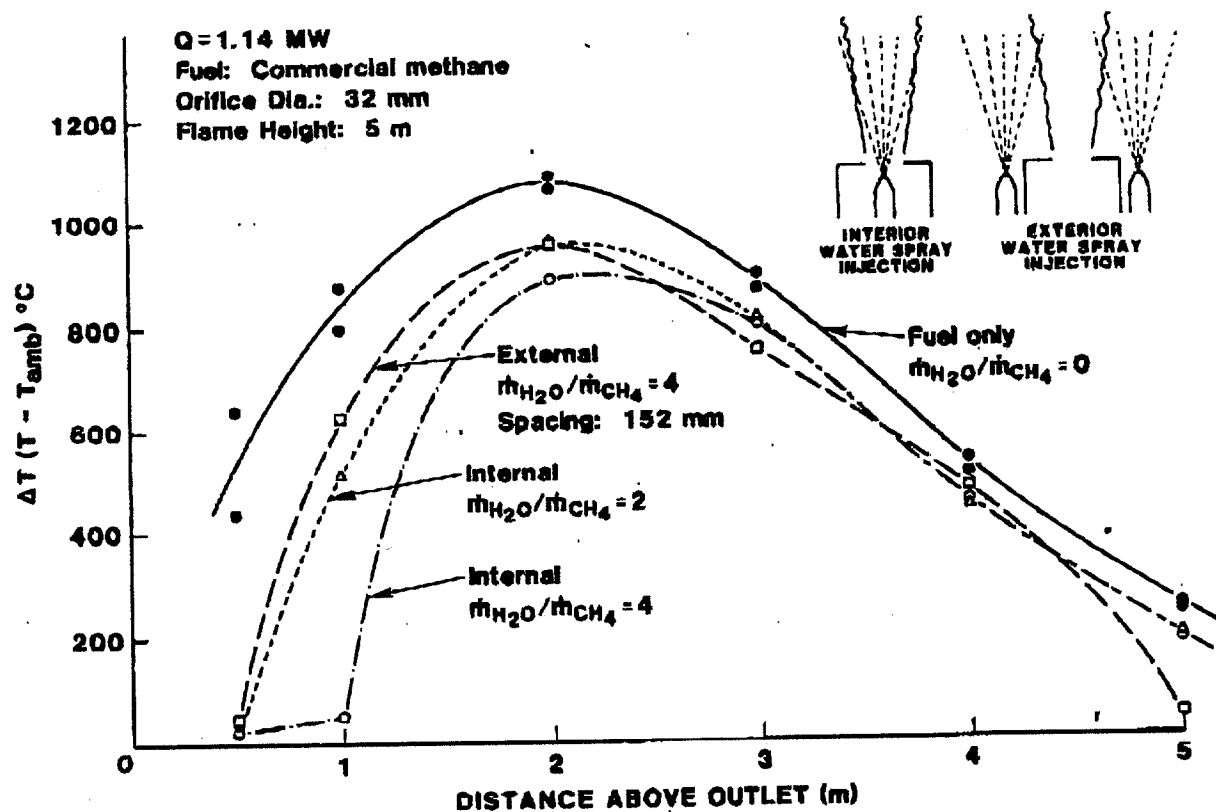


Figure 4.--Temperature rise on the axis of the jet flame.

From the research performed to date, it is concluded that steel structures in flames cannot be cooled sufficiently to prevent loss of material strength by injecting water sprays into the bulk of the combustion products. As a result, direct water spray or other thermal protection must be provided for the derrick structure, which is likely to be enveloped by a blowout fire, to prevent collapse.

Testing to date in this research project has been limited to laboratory and intermediate-scale fires. Large-scale fire tests are planned for the autumn of 1983. These large-scale fires will provide needed controlled fire-test data from which scaling relationships can be validated.

Based on completed work, it is expected that reliable scaling methods for the reduction of overall flame radiation will be developed and validated. However, knowledge of the scaling relationships for flame temperatures and extinguishment of the fires with water sprays are not complete. Scaling of fire extinguishment is complicated because high momentum flames can be extinguished with water sprays by a variety of mechanisms. Large gas fires are extinguished by water sprays predominately

by cooling and dilution of reactants. Small fires may be extinguished by this mechanism too, but, in addition, the flame may be blown off its support by the momentum of the water droplets and entrained air. The decrease in the importance of flame liftoff for large fires also complicates scaling of flame temperatures.

For most laboratory fires and some intermediate-scale fires studied in this project, fire extinguishment involved flame blowoff. This method of flame extinction, however, is not expected to be important for the large-scale fire-suppression experiments planned for this project or in actual blowout fires. Additional study of the extinction process and temperature distributions in the intermediate-scale-fire facility are planned to supplement information from large-scale test and to develop water-spray flame-cooling and extinguishment data under conditions for which flame blowoff in the absence of water spray is not possible.

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